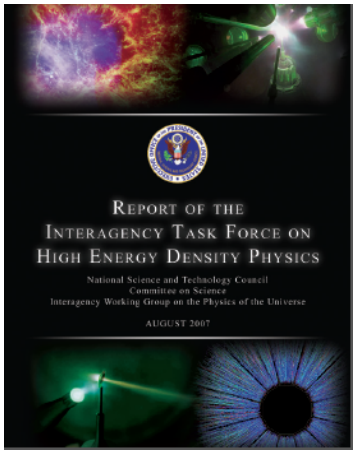
The Jupiter Laser Facility

Robert Cauble
JLF Director
NIF User Group Meeting

February 12-15, 2012

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Security, LLC, Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

DOE-sponsored reports have made recommendations for research in HED science



Action Item

Advancing research in High Energy Density Laboratory Plasmas (HED-LP) requires Federal organization and mechanisms for planning, management and merit-based, science-driven stewardship. The following actions will be implemented to address these deficiencies:

Strengthening university activities in high energy density laboratory plasmas will help advance the Nation's basic science mission goals and ultimately contribute to achieving major programmatic goals of DOE in nuclear weapons stewardship and fusion energy.

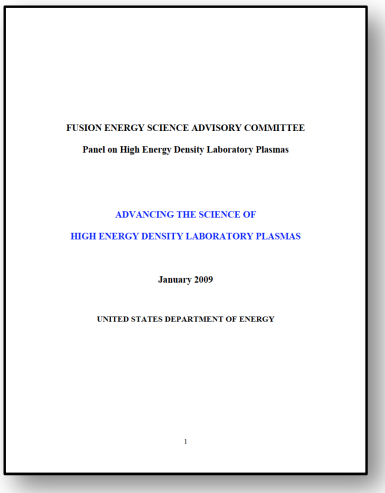
Appendix E. NNSA User Facility Programs

Facility Use Policies for major NNSA HEDP facilities

As part of the ongoing Complex 2030 effort to transform the weapons complex, NNSA is developing a policy for the operation of its HEDP facilities as national, shared facilities for programmatic and external user needs. The major facilities covered under this new policy are: the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL), Omega/Omega EP at the Laboratory for Laser Energetics (LLE) at the University of Rochester,* and the ZR/Z-Beamlet/Petawatt at Sandia National Laboratories (SNL).

NNSA expects that intermediate-scale facilities will also be covered under this policy: Trident at the Los Alamos National Laboratory (LANL), Jupiter Facility at LLNL, the Nevada Terawatt Facility (NTF) at University of Nevada at Reno, and other NNSA-funded facilities as appropriate. A small pilot program soliciting proposals for intermediate-scale facilities was recently initiated and the first awards will be made in FY2007.

DOE-sponsored reports have made recommendations for research in HED science



FUSION ENERGY SCIENCE ADVISORY COMMITTEE

Panel on High Energy Density Laboratory Plasmas

ADVANCING THE SCIENCE OF

HIGH ENERGY DENSITY LABORATORY PLASMAS

January 2009

UNITED STATES DEPARTMENT OF ENERGY

1

"Betti Report" for FES

Recommendation on facilities: *The current excitement surrounding HEDLP is based upon existing and near term large- and intermediate- scale experimental facilities in the U.S. that are capable of generating high energy density conditions. Taking full advantage of the opportunities described in this report over the next decade requires continuing and assured access for the broader scientific community to these facilities. Formal or informal user programs should be expanded, and new ones should be developed to increase access to HEDLP facilities. Modest facility upgrades will enable even more exciting and challenging experiments of high intellectual value.*

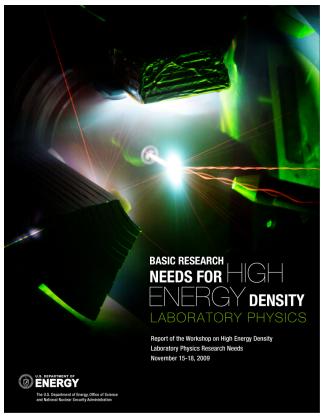
IV. A Scientific Roadmap for Energy-Related HEDLP Studies

1. Exploiting available facilities to explore energy-related HEDLP science
2. Exploiting the National Ignition Facility (NIF) capabilities to address ignition science issues related to inertial fusion energy
3. Resolving scientific issues to promote a transition from a burning plasma experiment to a fusion-energy-science development program.

Finding: *The NIF is likely to be oversubscribed during the next decade and the exploration of some of the IFE concepts would require significant modifications of the NIF, with associated costs of the new hardware and a loss of shot time while modifications are being performed. These concepts should be developed on existing HED facilities, with the most promising transferred to the NIF for a high-gain-ignition demonstration.*

Physical and Life SCIENCES

DOE-sponsored reports have made recommendations for research in HED science



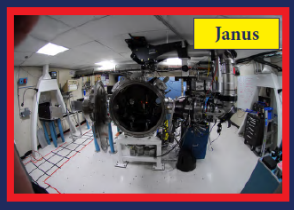
High Energy Density Laboratory Physics

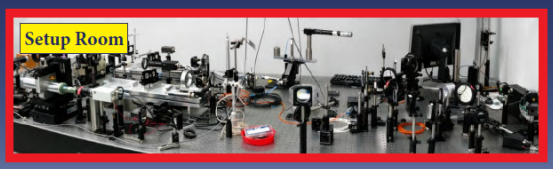
Within NNSA, the only facilities formally operating as a "Designated User Facility" are the Lujan Neutron Scattering Center at LANSCE (Los Alamos Neutron Science Center) and the Center for Integrated Nanotechnology at the Los Alamos and Sandia National Laboratories. These facilities are subject to both NNSA and Office of Science oversight. However, other NNSA facilities, such as OMEGA, and intermediate-scale laser facilities at the national laboratories also operate as user facilities part of the time. For that aspect of their operation, facility access is based upon peer review by external committees of discovery-driven science proposals. The National Laser User Facility (NLUF) Program that began in 1979 allows user access to the OMEGA facility and provides incremental funding to support basic HED science for university and private industry investigators.

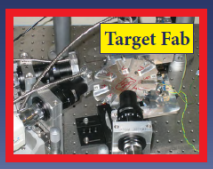
What's needed? Use of NNSA's shared national resources for science in the Nation's broadest interest can best be achieved by providing access to these facilities by the scientific community, consistent with NNSA's mission needs. Operating an SNR as a partial user facility requires funding well in excess of that required for minimum operation of the facility; funds for coordination, engineering and technical support, facility diagnostics, administrative support, etc. are also required.

Physical and Life SCIENCES

Jupiter Laser Facility







Expanding High Energy-Density Science

Jupiter is a multi-platform facility for HED science

Mission

- Expand the frontiers of high energy-density laboratory science
- Support high energy-density science at LLNL in multiple programs
- Support, collaborate with, and expand the broader HED physics community
- Help train and recruit future scientific workforce

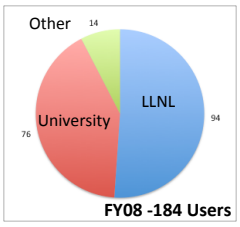
Physical and Life SCIENCES

Jupiter is a multi-platform facility for HED science

Approach

- Office-of-Science-style user facility where all laser time is provided free-of charge and apportioned through an open, competitive peer-review process
- On a scale that provides significantly greater laboratory access and potentially more flexibility than large-scale laser facilities
- With a variety of systems capable of front-rank HED science for different classes of experiments
- And the infrastructure to safely support multiple users with a range of experience levels

Number of active JLF users has significantly increased since becoming an open user facility



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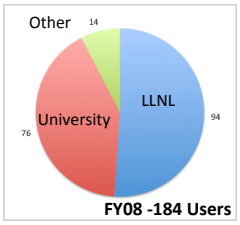
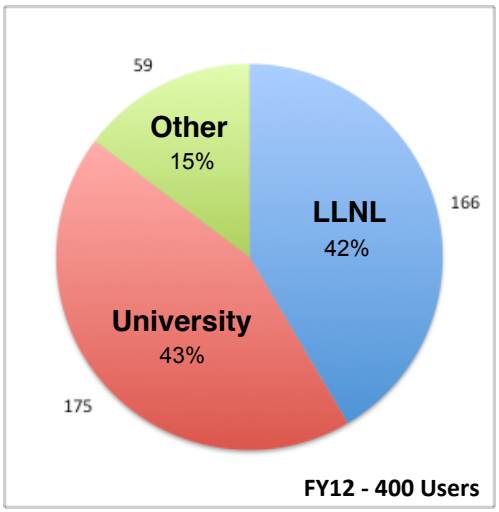




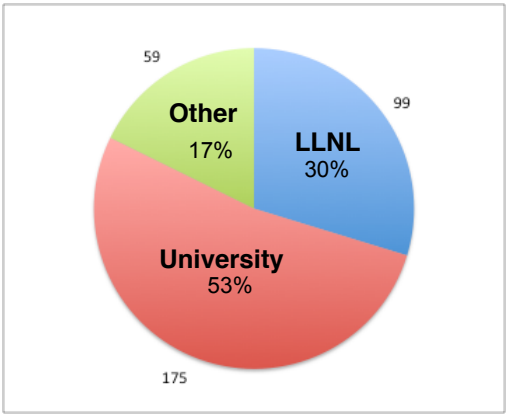
- **270 new faces in less than 4 years**

A number of organizations involved in HED science have active JLF users

LLNL	Universities		Other	
Engineering	Cal Poly	Chinese Acad Science	Alme/DTRA	AWE
NIF	Colorado St	Ecole Polytechnique	Carnegie Inst	CEA
PLS	Columbia	Heinrich-Heine U	GA	CNR/Pisa
WCI	Florida A&M	Imperial College	LANL	GSI
	Harvard	Inst Naz Fisica Nucl Italy	LBNL	JAEA Japan
	MIT	IST Portugal	LLE	KAERI Korea
	Ohio State	Osaka U	NRL	Kentech
	Princeton	Queen's U Belfast	NSTec	RAL
	Stanford	Shanghai Jiao Tong U	NTF	
	Texas A&M	Tech U Darmstadt	SLAC	
	U Arizona	Tech U Dresden		
	UC-Berkeley	U Alberta		
	UC-Davis	U Bordeaux/CELIA		
	UCLA	U British Columbia		
	UC-Santa Barbara	U Edinburgh		
	UC-San Diego	U Jena		
	U Colorado	U Milano		
	U Maryland	U Oxford		
	U Michigan	U Paris		
	U Nevada Reno	U Pisa		
	U Pacific	U Quebec		
	U Rochester	U Rome		
	U Texas	U Strathclyde		
	Vanderbilt	U Toronto		
		U York		

University and student participation at JLF is high

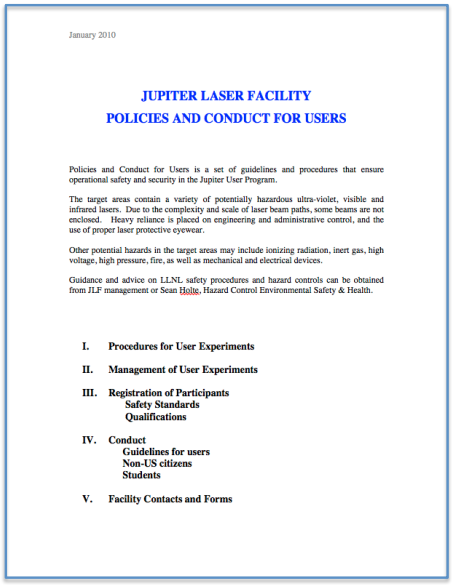
Experimentalists from Academia Dominate JLF "Science" Users



- **About 1/4 of all users – more than 1/2 of university users – are students**

JLF has the infrastructure to handle many and varied users who perform experiments

- Time allocated based on proposals presented to a technical review committee
  - based on scientific merit, impact, and feasibility
- Users must be registered
  - formal procedure: laser eye exam, safety courses, policy briefing, safety briefing, orientation
- Special provisions for students
  - line-of-sight supervision; work unsupervised with 3 months' experience and petition to JLF staff
- Lead experimentalists must be experienced
- Work performed under LLNL ES&H Manual regs using Integrated Safety Management processes (IWSs, Work Control, operational procedures, close contact with Safety Team)
- Experiments reviewed for readiness and teams debriefed on interaction



January 2010

JUPITER LASER FACILITY
POLICIES AND CONDUCT FOR USERS

Policies and Conduct for Users is a set of guidelines and procedures that ensure operational safety and security in the Jupiter User Program.

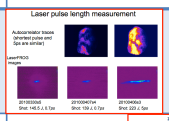
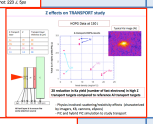
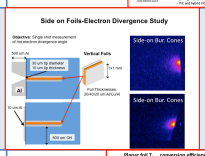
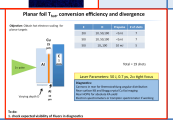
The target areas contain a variety of potentially hazardous ultra-violet, visible and infrared lasers. Due to the complexity and scale of laser beam paths, some beams are not enclosed. Heavy reliance is placed on engineering and administrative control, and the use of proper laser protective eyewear.

Other potential hazards in the target areas may include ionizing radiation, inert gas, high voltage, high pressure, fire, as well as mechanical and electrical devices.

Guidance and advice on LLNL safety procedures and hazard controls can be obtained from JLF management or Sean Hobbs, Hazard Control Environmental Safety & Health.

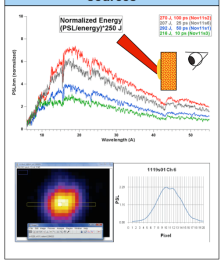
I. Procedures for User Experiments
II. Management of User Experiments
III. Registration of Participants
  Safety Standards
  Qualifications
IV. Conduct
  Guidelines for users
  Non-US citizens
  Students
V. Facility Contacts and Forms

Jupiter's user program includes DOE/FES-supported fusion science experiments at Titan

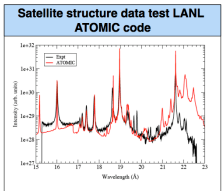
Activity		# Sci	# PD	# Stud	# Inst	PI
e^- source and time-resolved laser spot characterization		7	3	6	5	Y. Ping (LLNL)
Z effects on generation and transport		14	3	7	9	F. Beg (UCSD)
e^- source code benchmark, divergence measurements		6	3	8	8	C. Chen (LLNL)
e^- generation at 2ω (first 2ω shots on Titan)		7	3	10	6	R. Fedosejevs (U Alberta)

Some EOS and opacity measurement experiments were pioneered at JLF

Development of broadband x-ray sources



Satellite structure data test LANL ATOMIC code

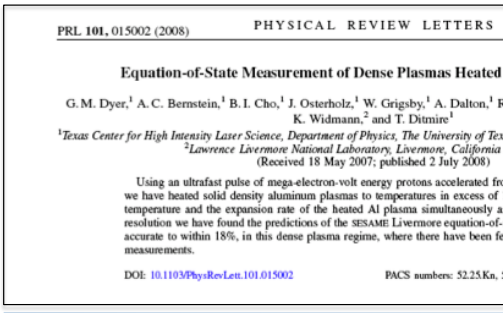


'Mixed' Two temperature spectra:

-99% hot, less dense (T_e = 150 eV, N_e = 3.6 x 10^{20} cm^{-3}) region

-1% colder, denser (T_e = 60 eV, Ne = 5 x 10^{22} cm^{-3}) region

J. Colgan, J. Abdallah, Jr., C. J. Fontes, D. P. Kilcrease
LANL ATOMIC code calculations (2009)



PRL 101, 015002 (2008) PHYSICAL REVIEW LETTERS week ending 4 JULY 2008

Equation-of-State Measurement of Dense Plasmas Heated With Fast Protons

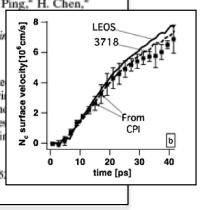
G. M. Dyer,[1] A. C. Bernstein,[1] B. I. Cho,[1] J. Osterholz,[1] W. Grigsby,[1] A. Dalton,[1] R. Shepherd,[2] Y. Ping,[2] H. Chen,[2] K. Widmann,[2] and T. Ditmire[1]

[1]Texas Center for High Intensity Laser Science, Department of Physics, The University of Texas at Austin, Austin
[2]Lawrence Livermore National Laboratory, Livermore, California 94550, USA

(Received 18 May 2007; published 2 July 2008)

Using an ultrafast pulse of mega-electron-volt energy protons accelerated from a laser-irradiate
we have heated solid density aluminum plasmas to temperatures in excess of 15 eV. By measuri
temperature and the expansion rate of the heated Al plasma simultaneously and with picosecon
resolution we have found the predictions of the SESAME Livermore equation-of-state (LEOS) table
accurate to within 18%, in this dense plasma regime, where there have been few previous experi
measurements.

DOI: 10.1103/PhysRevLett.101.015002 PACS numbers: 52.25.Kn, 52.27.Gr, 52.38.Ph, 5



REVIEW OF SCIENTIFIC INSTRUMENTS 79, 106104 (2008)

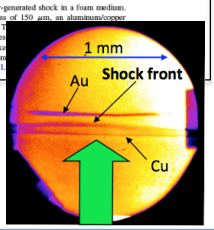
Density measurement of shock compressed foam using two-dimensional x-ray radiography

Sebastien Le Pape,[1] Andrew Macphee,[1] Daniel Hey,[1] Pravesh Patel,[1] Andrew Mackinnon,[1] Mike Key,[1] John Pasley,[2] Mingsheng Wei,[2] Sophia Chen,[2] Tammy Ma,[3] Farhat Beg,[3] N. Alexander,[4] Rich Stephens,[4] Dustin Offerman,[4] A. Link,[4] Lynn Van-Woerkom,[4] and R. Freeman[4]

[1]Lawrence Livermore National Laboratory, 700 East Avenue, Livermore, California 94550, USA
[2]University of California San Diego, La Jolla, California 92093-0417, USA
[3]General Atomics, California 92121-1122, USA
[4]Ohio State University, Columbus, Ohio 43210, USA

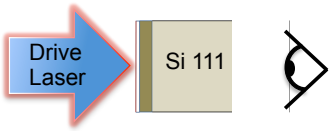
(Received 18 April 2008; accepted 25 August 2008; published online 10 October 2008)

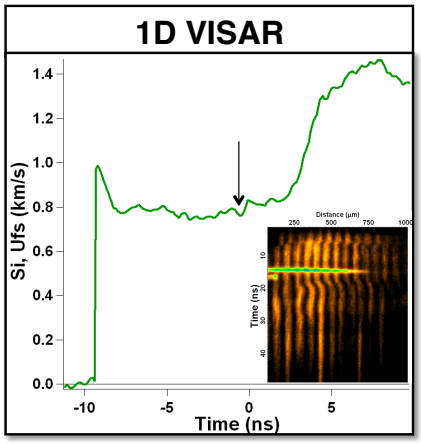
We have used spherically bent quartz crystal to image a laser-generated shock in a foam medium. The foam targets had a density of 0.16 g/cm³ and thickness of 150 μm, an aluminum/copper pusher drove the shock. The experiment was performed at the T
National Laboratory using a 2 ns, 250 J laser pulse to compres
(10 ps, 350 J) to generate a bright Ti Kα x-ray source at 4.5 ke
The crystal used gives a high resolution (~20 μm) monochrom
foam. [DOI: 10.1063/1.



Novel diagnostics are being developed at JLF

Courtesy Ray Smith, LLNL





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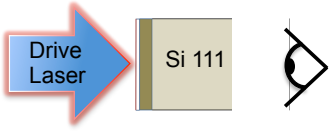
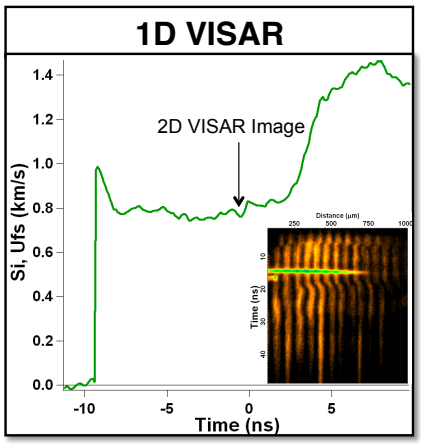
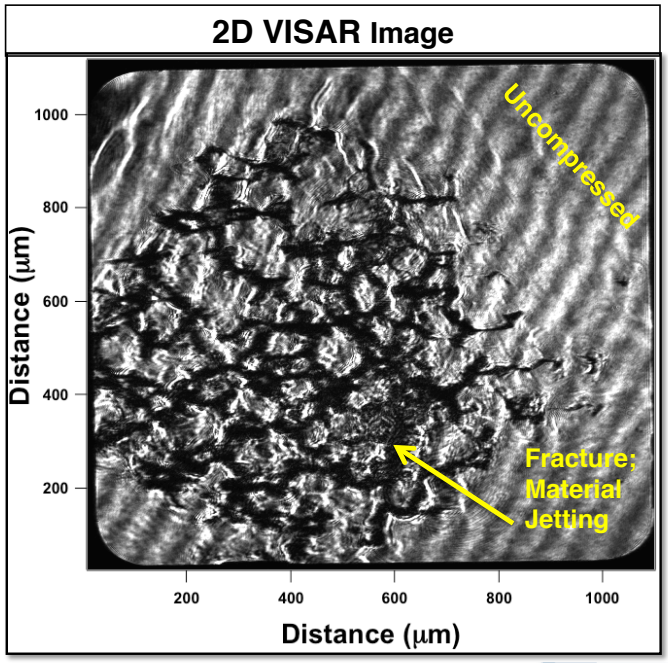
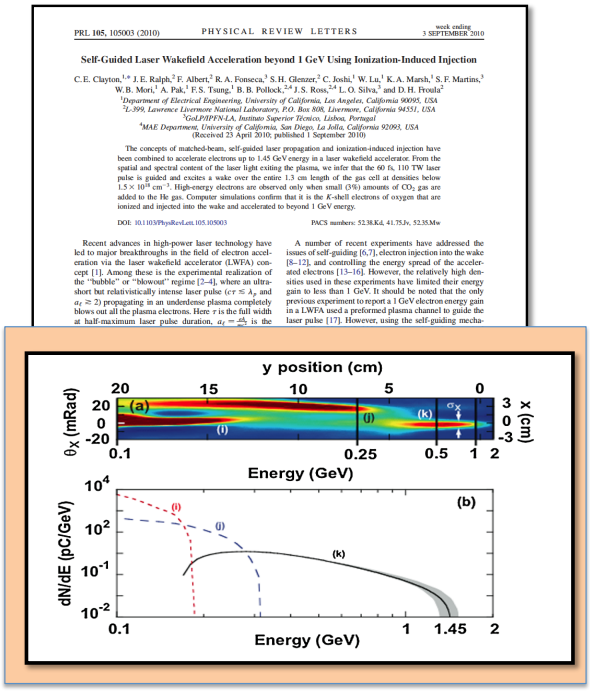






Record-pace wakefield acceleration measurements have been made recently on Callisto



PRL 105, 105003 (2010) PHYSICAL REVIEW LETTERS week ending 3 SEPTEMBER 2010

Self-Guided Laser Wakefield Acceleration beyond 1 GeV Using Ionization-Induced Injection

C. E. Clayton,[1,*] J. E. Ralph,[2] F. Albert,[2] R. A. Fonseca,[3] S. H. Glenzer,[2] C. Joshi,[1] W. Lu,[1] K. A. Marsh,[1] S. F. Martins,[3] W. B. Mori,[1] A. Pak,[1] F. S. Tsung,[1] B. B. Pollock,[2,4] J. S. Ross,[2,4] L. O. Silva,[3] and D. H. Froula[2]

[1]*Department of Electrical Engineering, University of California, Los Angeles, California 90095, USA*
[2]*L-399, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, California 94551, USA*
[3]*GoLP/IPFN-LA, Instituo Superior Técnico, Lisboa, Portugal*
[4]*MAE Department, University of California, San Diego, La Jolla, California 92093, USA*
(Received 23 April 2010; published 1 September 2010)

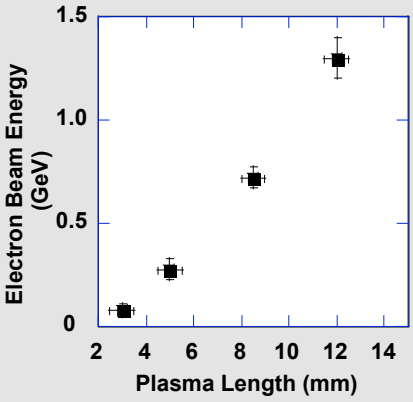
The concepts of matched-beam, self-guided laser propagation and ionization-induced injection have been combined to accelerate electrons up to 1.45 GeV energy in a laser wakefield accelerator. From the spatial and spectral content of the laser light exiting the plasma, we infer that the 60 fs, 110 TW laser pulse is guided and excites a wake over the entire 1.3 cm length of the gas cell at densities below 1.5×10^{18} cm^{-3}. High-energy electrons are observed only when small (3%) amounts of CO_2 gas are added to the He gas. Computer simulations confirm that it is the K-shell electrons of oxygen that are ionized and injected into the wake and accelerated to beyond 1 GeV energy.

DOI: 10.1103/PhysRevLett.105.105003 PACS numbers: 52.38.Kd, 41.75.Jv, 52.35.Mw

Recent advances in high-power laser technology have led to major breakthroughs in the field of electron acceleration via the laser wakefield accelerator (LWFA) concept [1]. Among these is the experimental realization of the "bubble" or "blowout" regime [2–4], where an ultrashort but relativistically intense laser pulse ($c\tau \lesssim \lambda_p$ and $a_L \gtrsim 2$) propagating in an underdense plasma completely blows out all the plasma electrons. Here τ is the full width at half-maximum laser pulse duration, $a_L = \frac{eA_L}{mc^2}$ is the

A number of recent experiments have addressed the issues of self-guiding [6,7], electron injection into the wake [8–12], and controlling the energy spread of the accelerated electrons [13–16]. However, the relatively high densities used in these experiments have limited their energy gain to less than 1 GeV. It should be noted that the only previous experiment to report a 1 GeV electron energy gain in a LWFA used a preformed plasma channel to guide the laser pulse [17]. However, using the self-guiding mecha-

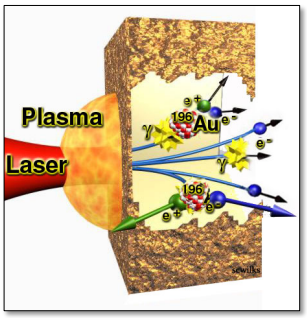
Electrons (1.5 pC) accelerated at 100 GeV/m

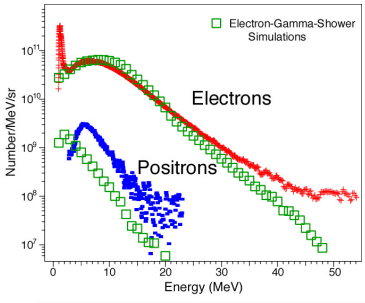


Courtesy Joe Ralph, LLNL; Chris Clayton, UCLA; Brad Pollock, UCSD; Dustin Froula, LLE

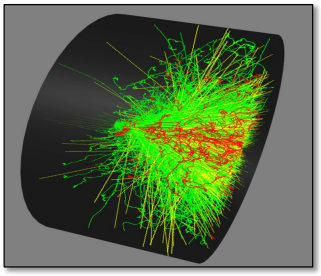
Physical and Life SCIENCES

Work on production of high-density positron jets began on Titan





Super hot electrons ($T_e \sim 9$ MeV)
10^{16} e^+/cm^3 inside target.
e^+/e^- ratio 100 times previous data



PRL 102, 105001 (2009) PHYSICAL REVIEW LETTERS week ending 13 MARCH 2009

Relativistic Positron Creation Using Ultraintense Short Pulse Lasers

Hui Chen,[1] Scott C. Wilks,[1] James D. Bonlie,[1] Edison P. Liang,[2] Jason Myatt,[3] Dwight F. Price,[1] David D. Meyerhofer,[3] and Peter Beiersdorfer[1]

PRL 105, 015003 (2010) PHYSICAL REVIEW LETTERS week ending 2 JULY 2010

Relativistic Quasimonoenergetic Positron Jets from Intense Laser-Solid Interactions

Hui Chen,[1] S. C. Wilks,[1] D. D. Meyerhofer,[2,3] J. Bonlie,[1] C. D. Chen,[1] S. N. Chen,[1] C. Courtois,[4] L. Elberson,[1] G. Gregori,[5] W. Kruer,[1] O. Landoas,[4] J. Mithen,[5] J. Myatt,[2] C. D. Murphy,[5] P. Nilson,[2] D. Price,[1] M. Schneider,[1] R. Shepherd,[1] C. Stoeckl,[2] M. Tabak,[1] R. Tommasini,[1] and P. Beiersdorfer[1]

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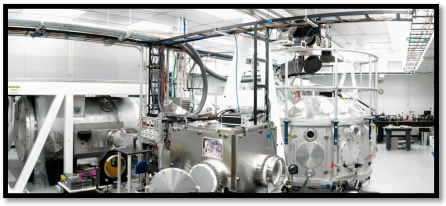
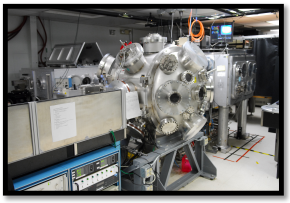
Physical and Life SCIENCES

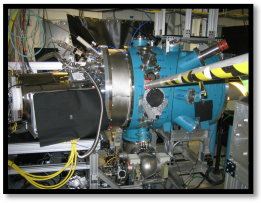
JLF laser platforms are heavily requested



- Titan shot-weeks over-requested by more than a factor of 2 in FY12
- 22 proposals submitted (involving 55 students and 30 PDs); 10 were approved

- Janus shot-weeks over-requested by almost a factor of 2 in FY12
- 18 proposals submitted; 10 were approved



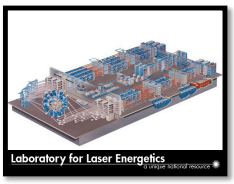


Callisto and COMET each over-requested in FY12

Physical and Life SCIENCES

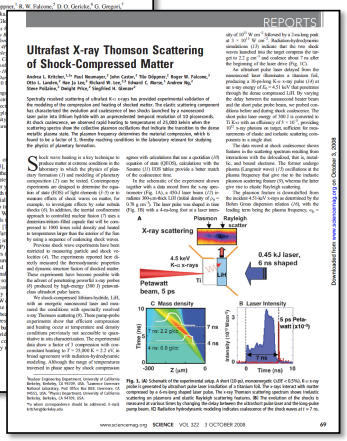
Jupiter is a development and proving ground for experiments and diagnostics that stage to larger facilities

Positron Jets (Titan)
Dynamic Deformation (Janus)
WDM EOS (Titan)
Fast Ignition Studies, High-Pressure EOS,
Thomson Scattering, X-ray Source Development,
Detector Development



PRL 103, 245004 (2009) PHYSICAL REVIEW LETTERS week ending 11 DECEMBER 2009

Measurements of Ionic Structure in Shock Compressed Lithium Hydride from Ultrafast X-Ray Thomson Scattering



REPORTS

Ultrafast X-ray Thomson Scattering of Shock-Compressed Matter

Downloaded from www.sciencemag.org on October 9, 2008

www.sciencemag.org SCIENCE VOL 322 3 OCTOBER 2008 69

PRL 107, 015002 (2011) PHYSICAL REVIEW LETTERS week ending 1 JULY 2011

In-Flight Measurements of Capsule Shell Adiabats in Laser-Driven Implosions

Physical and Life SCIENCES

Jupiter is a development and proving ground for experiments and diagnostics that stage to larger facilities

Positron Jets (Titan)
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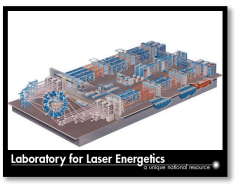
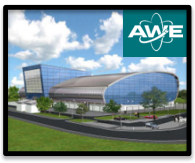


Pair Plasmas (Titan)
Thomson Scattering (Titan, Janus)
Planetary Science, EOS (Janus)
Ultrafast Detectors (Callisto)
X-ray Detector Qualification (COMET)

High-Temperature Opacity/EOS (Titan)



Innovation and flexibility to adapt to new experimental scenarios are key for intermediate-scale facilities

The following modifications were done at the request of experimenters

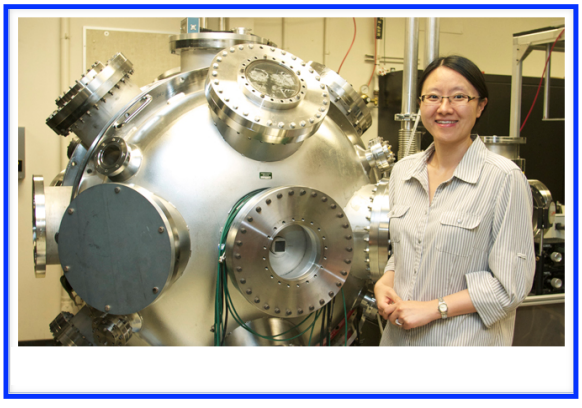
- **Filled the Janus chamber with low-density gas for a laser-plasma interaction experiment**
- **Transported and synched the Callisto beam to the Janus Target Area**
- **Changed the Titan optics for a 4ω Thomson scattering experiment**
- **At the request of two different users, we changed out optics to frequency-double the Titan short-pulse (ps) beam**
- **We split the Titan short-pulse beam into two beams for experiments that required two short-pulse laser beams**

JLF does a lot with fairly minimal resources

- **Typically 15 to 30 users in building each day performing 3-4 experiments simultaneously**
- **Full single-shift capacity is ~1800 high-energy laser shots in 44 shot-weeks with a staff of 13 (however capacity is now reduced)**
- **Jupiter attempts to fulfill the need to enhance HED science and program needs, augment the user community, and train new scientists – a place where researchers can come to gain insight in an environment where insight and success may not be the same thing**
- **JLF is a user facility without an official user group. There are numerous issues to discuss and I encourage users of JLF, and potential users, to form one.**

Physical and Life SCIENCES

Yuan Ping wins 2011 tri-annual APS Katherine E. Weimer Award for young female physicist in plasma science



Yuan standing by one of the Europa target chambers where she did many of her experiments researching plasma physics and warm dense matter.

Physical and Life SCIENCES

Jupiter Laser Facility
Titan Laser

Combined long-pulse 1-kJ and short-pulse PW-class beams

	Long-Pulse Beam		Short-Pulse Beam	
λ	1053 nm	527 nm	1053 nm	527 nm
Pulse	0.35-20 ns	0.35-20 ns	0.7-200 ps	0.7-200 ps
Energy	Up to 1 kJ	Up to 500 J	Up to 300 J	Up to 50 J
Best Focus/ Phase Plates	20 μm/ 200-1000 μm	20 μm/ 200-1000 μm	8 μm	8 μm
Rep Rate	2/hr	2/hr	2/hr	2/hr

Jupiter Laser Facility
Janus Laser

Two independent long-pulse (ns) 1-kJ beams

Both East and West beams have the following capabilities		
λ	1053 nm	527 nm
Pulse	0.35-20 ns	0.35-20 ns
Energy	Up to 1 kJ	Up to 500 J
Best Focus/ Phase Plates	20 μm/ 200-1000 μm	20 μm/ 200-1000 μm
Rep Rate	2/hr	2/hr

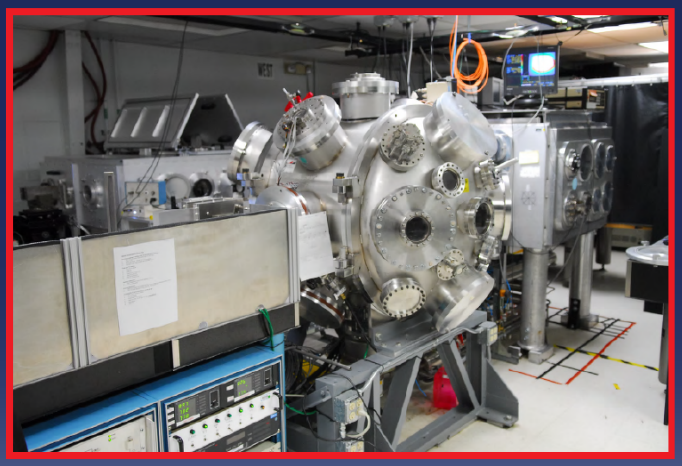
- Short-pulse 50-mJ probe available
- Beam synch continuously variable; 50 ps jitter
- VISAR and SOP are permanent diagnostics

Target chamber accepts multiple beam positions

Jupiter Laser Facility
Callisto Laser

Sub-100-fs laser capable of 200 TW in single-shot mode

Capabilities		
Mode	High Rep	Single-Shot
λ	800 nm	800 nm
Pulse	60 fs	60 fs
Energy	120 mJ	12 J
Best Focus	5 μm	5 μm
Rep Rate	10 Hz	2/hr
– 5-mJ, 60-fs probe available		

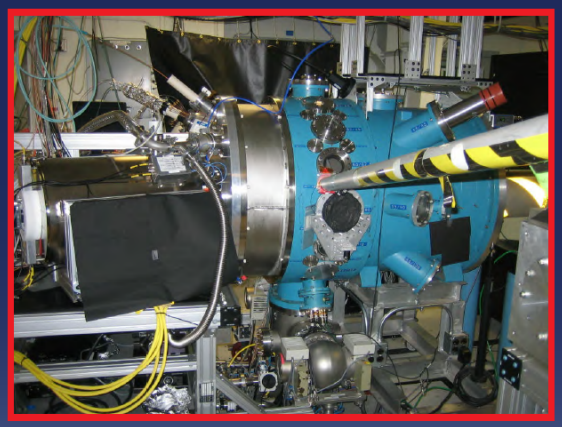


Two available target chambers

Jupiter Laser Facility
COMET Laser

COmpact MultipulsE Terawatt - a versatile multibeam system

Capabilities			
Beam #	1	2	5
λ	1053/527 nm	1053/527 nm	1053/527 nm
Pulse	0.5-260 ps	750 ps	0.5-6 ns
Energy	15/8 J	10/20 J	20/10 J
Best Focus	7×10 μm	2× Diff Limit	2× Diff Limit
Rep Rate	15/hr	15/hr	15/hr
– Two additional long-pulse/short-pulse lines (Beams 3 and 4) available – Beams 1-4 can be operated simultaneously			



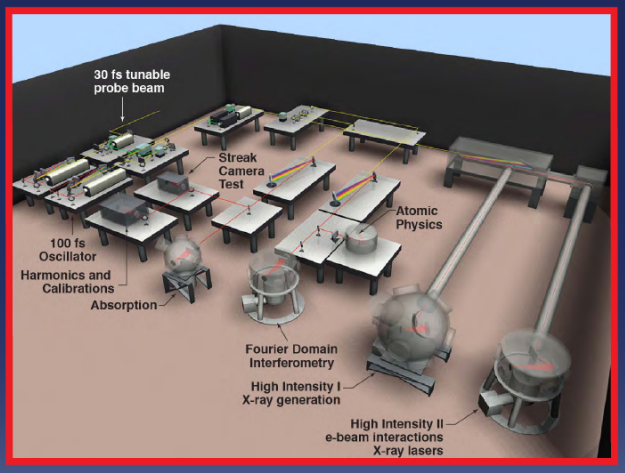
COMET can operate several beams concurrently with a 4-minute cycle time between shots

Jupiter Laser Facility
Europa Laser

20-mJ 120-fs, 10-Hz Ti:Sapphire system

Capabilities		
λ	800 nm	400 nm
Pulse	120 fs	100 fs
Energy	20 mJ	6 mJ
Best Focus	3× Diff Limit	3× Diff Limit
Rep Rate	10 Hz	10 Hz

– Pulses can be multiplexed
– Multiple target chambers



Europa is a well-equipped system especially suitable for configuration tests and training

Physical and Life SCIENCES